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DESIGN DEFINITION STUDY REPORT. FULL CREW INTERACTION SIMULATOR--ETC
MAY 78 N61339-77-C-0185
UNCLASSIFIED LR-895-VOL-7 NAVTRAEQUIPC-77-C-0185-000 NL

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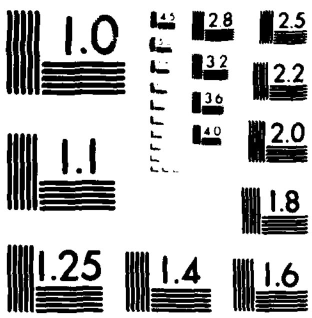
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INVENTORY

Singer Co., Binghamton, NY
Link Div.
Rpt.No. LR-895, Volume VII, Final, June 1978
Rpt.No. NAVTRAEQUIPCEN 77-C-0185-0001, v.7

DOCUMENT IDENTIFICATION

Contract No. N61339-77-C-0185

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Design Definition Study Report

Full Crew Interaction Simulator

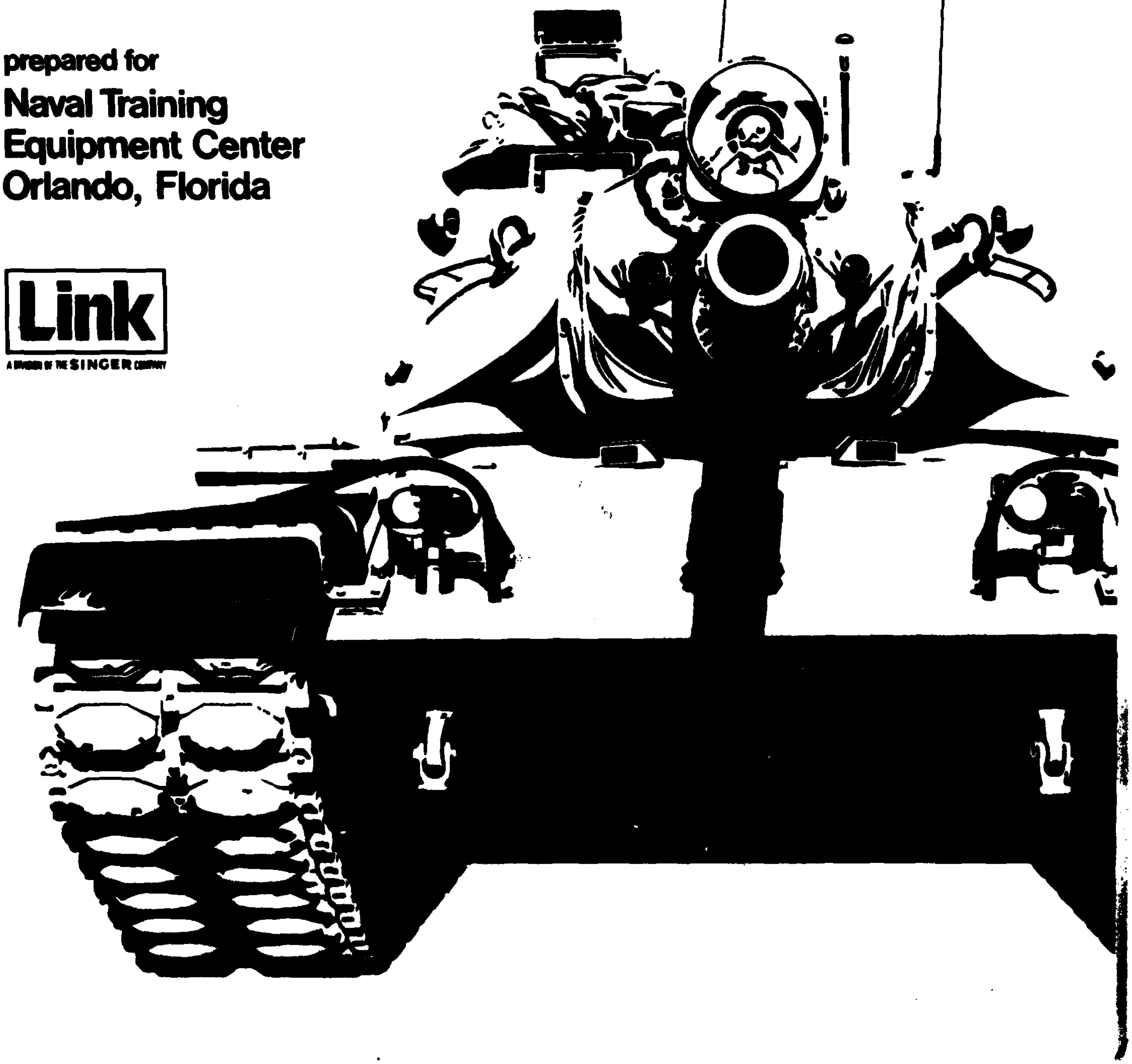
Laboratory Model (FCIS-LM) Device X17B7

prepared for

Naval Training Equipment Center
Orlando, Florida

Link

A DIVISION OF THE SINGER COMPANY



Report No: NAVTRAEQUIPCEN 77-C-0185-0001
LR-895

DESIGN DEFINITION STUDY REPORT

FULL CREW INTERACTION SIMULATOR-LABORATORY MODEL

(DEVICE X17B7)

VOLUME VII - CONCLUSIONS

Link Division, The SINGER COMPANY
Binghamton, New York 13902

FINAL
May 1978

Prepared for:
NAVAL TRAINING EQUIPMENT CENTER
Orlando, Florida 32813

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NAVTRAEQUIPCEN 77-C-0185-0001	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) DESIGN DEFINITION STUDY REPORT FULL CREW INTERACTION SIMULATOR-LAB. MODEL (DEVICE X17B7)		5. TYPE OF REPORT & PERIOD COVERED Final June 1978
		6. PERFORMING ORG. REPORT NUMBER LR-895
7. AUTHOR(s)		8. CONTRACT OR GRANT NUMBER(s) N61339-77-C-0185
9. PERFORMING ORGANIZATION NAME AND ADDRESS Link Division, The SINGER COMPANY Binghamton, New York 13902		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS NAVAL TRAINING EQUIPMENT CENTER Orlando, Florida 32813		12. REPORT DATE June 1978
		13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; Distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Report consists of twelve sections bound in 7 volumes.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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SECTION XII

12. STUDY CONCLUSIONS AND RESULTS

This conclusion section presents a review of the study areas together with summaries of performance, complexity, cost, reliability and maintainability for each of the major subjects/problems investigated.

12.1 General Description of FCIS-LM Device

Figure 12-1 is a high level block diagram of the recommended FCIS-LM. The basic design consists of two crew stations, one for the driver, and one for the fighting compartment. Each crew station has a visual system and both visuals are driven by the Digital Image Generator (DIG). The DIG interfaces via a data link with the IOS, for performance monitoring and problem control, and to the main simulation computer for dynamics and ballistics system synchronization. The simulation computer, in turn, performs the real-time execution of the simulation math models.

Figure 12-2 expands the overall FCIS-LM system flow in greater detail, and shows how various control functions interface with the simulation computer and interact to produce the required responses. The major systems comprising the FCIS-LM are the crew station visual system, motion system, instructor station, and computer complex.

As previously noted, there are two crew stations, the driver compartment and the fighting compartment. Both simulated compartments will be complete with instruments, panels, and furnishings identical in appearance, color, feel, and function to those of the tank. All operating controls will be monitored by the computational system and the resulting indications will be driven by the computation system in response to real-time computer programs. Firing effects of the main gun, coaxial machine gun, and the tank commander's machine gun will be simulated. The exterior of the both compartments will be constructed to resemble the tank exterior because "out the hatch" viewing capability is provided for the tank commander, driver and loader. Appropriately located speakers will provide accurate and realistic aural cues within the trainee compartments.

A six-degree-of-freedom motion system will be provided for each crew station. The motion cues are considered most important to the training of crew task performance in the fighting compartment, and are necessary for training realism. The driver also depends heavily on motion cues to perform his tasks correctly.

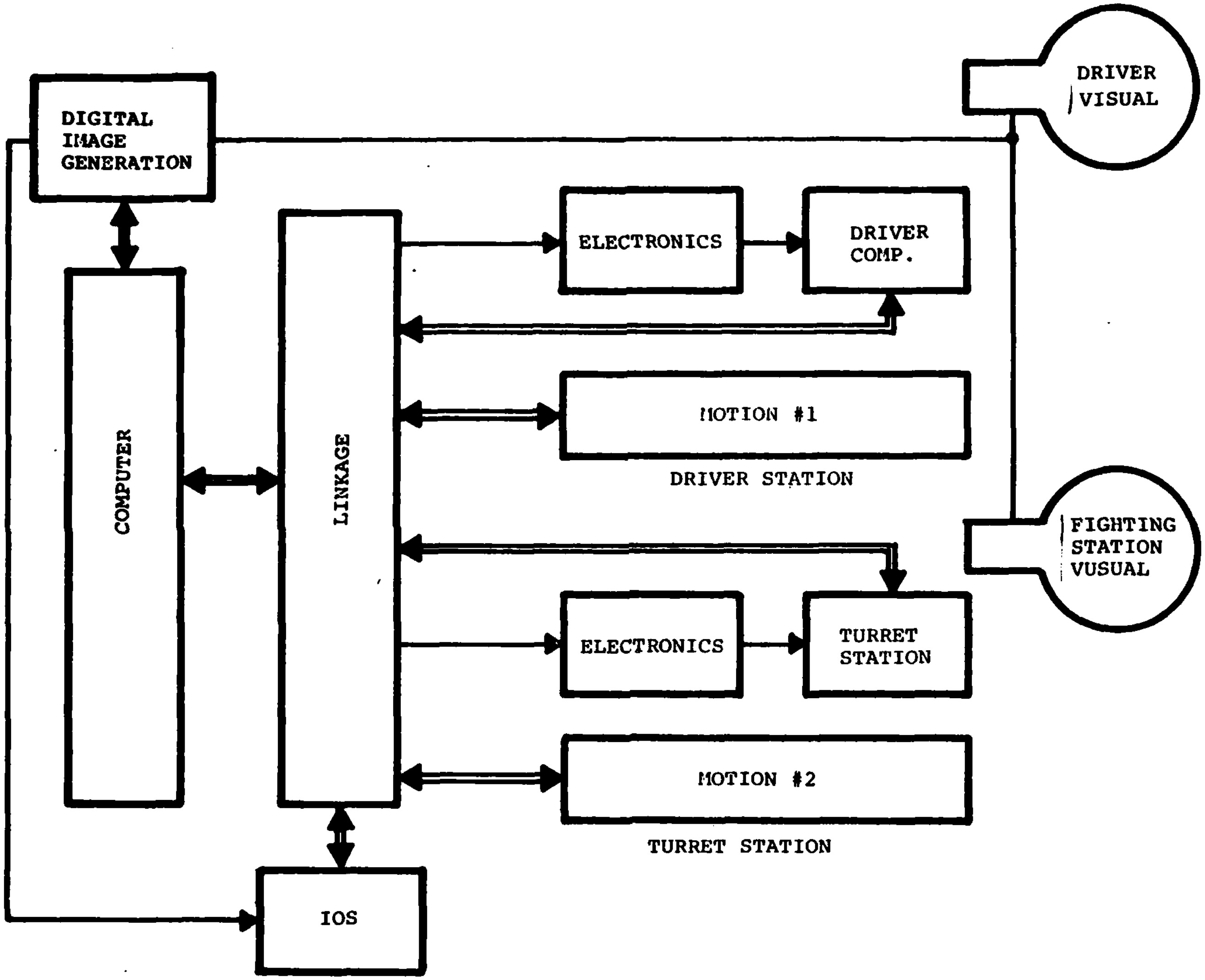

Figure 12-1 FCIS-LM Simplified Block Diagram

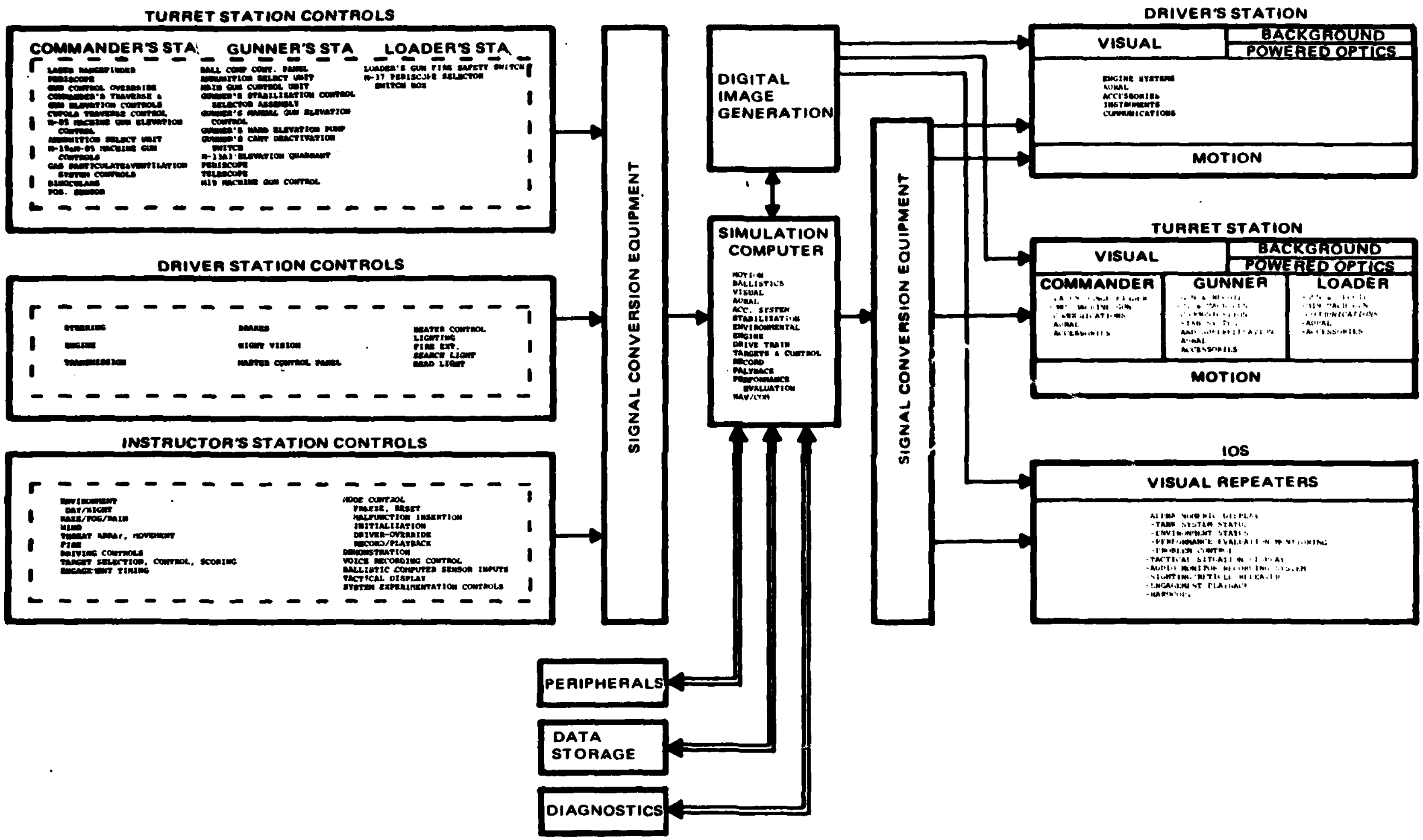

Figure 12-2 FCIS-LM Expanded Functional Diagram

The instructor station design concept for FCIS includes a display system and keyboards, plus driving and mode control panels and visual repeaters. It is designed to interface directly with the computation system. Controls are provided to enable the instructor to control the simulator subsystems during training. Control of simulation is via keyboards interacting with the CRT display system, which display the information required to monitor, guide, and evaluate student performance. The design configuration provides the instructor with the means of interacting with the simulator with minimum fatigue. Instructional features include record/playback with communications audio, problem formulation, and performance monitoring and scoring, and are designed to provide maximum training value for this complex interactive crew situation.

The computer complex configuration has been baselined as a 32-bit computer in a multiprocessor configuration interfaced through common memory. The current generation of 32-bit computers offers proven FORTRAN compilers as well as maximum system flexibility and expansion capabilities.

The computational system will include all interface and signal conversion hardware, simulator peripheral equipment, and operating software required for simulation control. The signal conversion equipment (SCE), a product of Link Division's Advanced Simulation Technology (AST) program, provides a reduction in system hardware, simplification of interface cabling, and a high degree of modularity in design. Simulation software will maximize the use of FORTRAN and will utilize top-down structured programming techniques.

12.2 Reliability/Maintainability Goals

Hardware needed to meet the FCIS training requirements has been defined conceptually. Feasibility studies have been conducted on the conceptual simulator to establish desigh objectives. These objectives have been developed by extrapolating data on existing systems of the same type and relative complexity to the FCIS conceptual design. The objectives so derived are defined in Table 12-1.

12.2.1 Reliability/Maintainability Features. The FCIS program will incorporate the use of a unique packaging technology; a relatively new concept in simulation developed by Link. Some of the features of this technology that enhance reliability and maintainability are:

1) Automatic test features which provide a significant reduction in equipment maintenance time and cost.

2) Closed Loop Linkage Testing provides fault isolation capabilities throughout the system.

3) Accessibility to card cages both front and rear which greatly reduce system restoration time while performing corrective maintenance.

TABLE 12-1 RELIABILITY/MAINTAINABILITY OBJECTIVES

Subsystem	MTBF	MTTR
Driver Station	364	40
Turret STation	201	40
Visual	85	39
Computer	225	45
IOS	408	42

MTBF = 37.9 Hours

MTTR = 41. Minutes

4) Serial data transfer hardware which significantly reduces the hardware required to perform specific simulation functions.

5) Rack-mount power supplies that include fault detection and monitoring of outputs which in the event of failure are removed from the local power buses to prevent inadvertent damage to aircraft cards and instruments.

6) Six-degree-of-freedom motion system which employs advanced development concepts to provide significant improvements in motion performance.

7) Easier maintenance due to a high degree of component commonality.

8) The "system on a card" design concept which enables fault isolation to the PC card level with a minimum amount of support equipment required.

In addition, the FCIS conceptual design will be implemented with hardware previously used on programs which have already undergone formal reliability/maintainability programs including formal demonstration tests. Some of the FCIS hardware previously used on past programs include the following:

1) Six-degree-of-freedom motion system

2) Display hardware

3) Computer hardware

4) Computer peripherals

5) Signal conversion equipment.

Most of these subsystems have all undergone formal reliability/ maintainability tests on such programs as UPT, 2B31, and 2B33. For these reasons Reliability Engineering is confident that the proposed values of reliability and maintainability can be achieved.

12.3 Visual System Characteristics

Table 12-2 itemizes actual FCIS visual system performance relative to the design goals established in Section 8.18 (Table 8-10)

TABLE 12-2 VISUAL SYSTEM PERFORMANCE CRITERIA

Item	Desired	Actual
Commander FOV (Out of Hatch)	± 90° Horizontal +30, - 25° Vertical	± 100° Horizontal + 43.75°, -20° Vertical
Loader FOV (Out of Hatch)	± 90° Horizontal +30, - 25° Vertical	± 100° Horizontal + 43.75°, -20° Vertical
Driver FOV (Out of Hatch)	± 40° Horizontal +30, - 5° Vertical	± 100° + 35°, -24
Optical Instruments FOV	Real World Characteristics	Real World Characteristics
Unity Power Scenes Resolution	10 Arc Minutes/ Line Pair	11.2 Arc Minutes/ Line Pair
Optical Instruments Resolution	11 Arc Minutes/ Line Pair to Eye	11.11 Arc Minutes/ Line Pair Average
Brightness	> 3 Foot Lamberts	6 Foot Lamberts
Scenic Requirements	See Section 8.18	All Scenic Requirements can be met
Special Effects	See Section 8.1.8	All but Heat Shimmer

12.4 Vehicle Dynamics and Motion System Characteristics

12.4.1 Vehicle Dynamics. The equations of motion are divided into translational and rotational equations. The translational equations of motion are computed with respect to a fixed axis system and the rotational equation of motion will be computed with respect to a body axis system. The Link approach will use the static and kinetic coefficients of friction, and rolling and grade resistances in their translational equation of motion (see Table 12-3). The rotational equation of motion due to the tank traversing the terrain will be kinematically simulated. The rate of turn will be a function of torque of the transmission, vehicle velocity and separation of the tracks.

Since the visual system is a DIG, rather than a camera/model system, the static and kinetic coefficients of friction and the roughness factor required by the suspension system will be correlated with the soil/terrain beneath the tank.

This approach satisfies the FCIS training requirements and the performance requirements as specified in the document SOW 2234-016.

TABLE 12-3 SOIL CHARACTERISTICS

Items	Recommended for FCIS
SOIL THRUST	
o Bekker's Equation	No
o Perloff's Equation	No
o Static Friction	Yes
o Kinetic Friction	Yes
o Slip	No
MOTION RESISTANCES	
o Compaction Resistance	No
o Bulldozing Resistance	No
o Grade Resistance	Yes
o Rolling Resistance	Yes
TYPES OF SOIL	
o Predominantly Cohesive	No
o Predominantly Friction	Yes
o Cohesive, Friction Mix	No
o Visual System Interface	Yes
o Correlation to Visual	Yes
o Effect of Weapon Fire	Yes

12.4.2 Motion System Characteristics. This section presents the characteristics of the recommended motion system. The evolutionary process of the study effort has caused a considerable departure from preconceived notions concerning tank simulator motion requirements. The metamorphosis has been from extremely limited motion to a configuration which employs two six-degree-of-freedom motion systems, one for the driver's station and one for the fighting station. It was found that the six degrees of freedom not only offered a great deal of experimental flexibility but also emerged as a virtual requirement at the fighting station.

Also emerging from this study was a requirement to provide vibratory cues of at least 5 Hz. The performance criteria were tabulated in Section 9.1 and are repeated here in Table 12-4. It was established that these motion systems be mounted on pedestals to avoid collision with the floor. It was further determined that the platform should be modified to accommodate the 28 foot diameter display dome. The remaining characteristics are those which have become standard for aircraft motion simulation systems and are included in Attachment 1 to Volume IV.

TABLE 12-4 MOTION SYSTEM CHARACTERISTICS

Degree of Freedom	Displacement	Velocity	Acceleration
Yaw	± 13°	± 20°/sec	± 2.0 rad/sec^2
Pitch	50° Total	± 17.5°/sec	± 60°/sec^2
Roll	± 20°	± 20°/sec	± 60°/sec^2
Vertical	± 15 in	± 25 in/sec	± 1.0g
Longitudinal	± 10 in	± 15 in/sec	± 0.6g
Lateral	± 10 in	± 15 in/sec	± 0.6g

12.5 Vehicle Systems Characteristics

12.5.1 Accessory Systems. The following list of accessory systems were studied in terms of hardware and software simulation feasibility:

- Fuel System
- Turret Hydraulic Systems
- Driver Controls and Indicators
- Gas Particulate System
- Electrical System
- Environmental Systems
- Fire Extinguishing System

The conclusions are that there is no unusual system anomalies in the hardware or systems functions that cannot be readily simulated using past experience in these system types. Most tank accessory systems can be directly related to aircraft accessory systems of which, Singer has produced many aircraft simulation devices. The tank accessory will be simulated to meet their requirements of the FCIS-LM (device X17B7) as determined by SOW 2234-016.

Aural System Conclusions and Recommendations

The aural system for the FCIS-LM will provide realistic sounds of the tank, guns, turret equipment and driving in response to SOW 2234-016.

Sounds will be produced by synthetic means (i.e., oscillator, white noise generators, filters, mixers, and audio amplifiers). The sounds, although unique to tanks and their equipment, can be realistically reproduced by this special equipment. Singer has historically produced a large number of unique sounds as required in aircraft simulators and the uniqueness of the tank sounds should present no particular simulation design problems.

The amplitude of the gun sounds in the tank, if simulated realistically, could pose a safety problem to personnel in the simulator and simulator area. Thus it is recommended that a maximum safe level setting be incorporated in the sound system level control.

12.5.2 Weapon Systems

Main Gun

Performance

- Feel and response of powered and manual elevation/traverse controls duplicated
- Recoil rate can be modified to reduce hazard
- Variable shell ejection
- Handling characteristics of simulated ammunition similar to actual, 5 ammunition types, verification of round type loaded
- Positive removal and storage of "fired" projectiles
- Misfired rounds removable
- Replenisher tape, reflects condition of recoil system
- Critical mechanisms and interfaces are duplicated
- Hazardous areas (for loader) are interlocked
- Three-second cycle rate (ready for reload)
- Servo-driven indicators.

Complexity

- Gun controls will be operational equipment
- Recoil system utilizes standard Singer control loading techniques
- Shell ejection, accomplished by actual tank mechanism
- Simulated ammunition - positive-locking of projectile/casing, easy reassembly, simple mechanism
- Transport/storage system utilizes all simple mechanisms and straightforward servo requirements.

Operating Cost

- Reusable ammunition will exhibit minimal replacement since positive storage system and rugged construction will greatly reduce damage due to mishandling.

Reliability

- Tank equipment - breech, hydraulics, etc., have proven service
- Recoil system employs field-proven Singer hardware
- Positive action of transport system mechanism, will assure good performance.

Maintainability

- No special tools
- Access compatible with normal tank maintenance.

Machine Guns

- Dummy ammunition belts for loading
- Manual/automatic firing
- Safety position sensor
- Loaded weapon sensors
- Rate-of-fire sensor.

12.5.3 Ballistic Computer. Software simulation has been determined to be the most desirable approach for simulator implementation of the XM21 Ballistic Computer functions. This determination has been based on analysis of performance and cost criteria associated with the various feasible approaches and on the compatibility of each approach with the overall trainer system configuration dictated by related trade-off studies and/or by simulation oriented requirements. The following features summarize the advantages of software simulation as opposed to the alternate approaches (including use of an unmodified XM21):

- Comparable performance capability such that operation of an XM21 will be faithfully duplicated
- Greatest system compatibility
- Allows for optimum correlation management between ballistic equations and real-time trajectory computations
- Lowest operation cost
- Maximum reliability
- Zero maintenance
- Maximum flexibility.

12.6 Instructional Systems

The FCIS instructional system considered crew training and evaluation, experimentation, and system and method validation to a degree never before attempted in armor training. Positions for up to three instructors and one experimenter are designed to allow real-time observation and control of virtually every aspect of the operational environment, every training-related system in the simulated tank, and every action of the crew.

Instructors may observe "over-the-shoulder" at either the turret or the driver station while controlling the training problem, monitoring tank and environmental parameters, and coordinating activities with each other and the main instructor/experiment station.

The main station will be remotely located from the two crew stations and will be the main operations center for both training and experimentation. The instructor at this location will have full control over the tactical environment and simulated tank system via an alphanumeric/dynamic tactical map color CRT. In addition to system monitoring and modification and crew performance and evaluation displays, this CRT will provide real-time threat and friendly positions, movements, and strengths relative to the terrain. The instructor will be able to adapt the complexity of the situation to the capabilities and requirements of individual crew members and of the crew as a whole. He will also be able to demonstrate situations and techniques, play back crew performance through all cueing systems, and make permanent records of performance monitoring and scoring information. He will also be able to observe any driver or turret visual scene channels while simultaneously monitoring whichever special viewing system the gunner or tank commander is using (including binoculars) using two visual system repeaters at his station.

The experimenter will sit beside the main instructor with his own alphanumeric CRT and controls. He will be able to monitor and control training when no instructor is required or he may observe and evaluate the instructor or aid him during heavy loads. The experimenter will also modify necessary experimental parameters and collect and store data as required.

12.6.1 Instructional System Hardware Characteristics

Display System

The recommended approach for the FCIS display system is the raster display system described in Section 11.1. Its characteristics are summarized below:

Performance - High

Operating Cost - Low

Complexity - Medium

Reliability - Medium

Maintainability - Medium

Record/Playback Audio System

The recommended approach for the FCIS record/playback audio system is the digital voice system described in Section 11.1. Its characteristics are summarized below:

Performance - High

Operating Cost - Low

Complexity - Low

Reliability - High

Maintainability - Low

12.6.2 <u>FCIS Configurations</u>. In the study sections, the advantages of pre-formulated problems — lessened instructor workload, standardized training, and trainer evaluations were described. Generation of first-rate pre-formulated problems, like the writing and publishing of field manuals, require levels of effort and expertise beyond that which can be expected of unit level installations. Hence, such pre-formulated problems should be generated at a central facility (Support Center) possessing the hardware, software, and personnel resources needed. Such exercises should be distributed to and used by the unit installations.

It is anticipated that the Support Center would operate as follows:

The Support Center would have an FCIS time block, a portion of which is dedicated to preprogrammed mission generation (as contrasted with crew training <u>per se</u>). The Support Center would also have data resources and experts in such areas as intelligence, tactical doctrine, training technology, and unit training needs. With these resources, the Support Center would:

1) Generate a set of pre-formulated training exercises for each unit installation, providing not only the disks containing the software defining a particular exercise, but also important auxiliary material such as instructor guides, crew briefing material, guides to instructors, and crew personnel in interpreting scores, etc.

2) Train unit-level instructors in the use of the FCIS.

3) Assemble data on FCIS utilization, trainee performance, unmet training needs, etc.

4) Modify the original set of training exercises to reflect current equipment, doctrine, intelligence data, and training needs on a continuing basis.

5) Monitor FCIS employment to assure that training requirements are met.

It is anticipated that the FCIS at the Support Center would be used part of the time in its Support Center role, and part of the time for unit level training. While this dual use will require careful scheduling, it provides the developers of pre-formulated exercises with a nearby laboratory to test the exercises and supportive training materials.

12.7 Computer Systems Characteristics

The computer system requirements for the FCIS(LM) have been developed based on performance parameters, initial and life cycle cost, and additional criteria as discussed in previous sections of this report. Primary computer system performance parameters which have been considered are:

- o Computation speed and accuracy
- o Operating system capabilities
- o Compiler efficiency
- o Executive software capabilities
- o Support software capability

Additional criteria of prime importance which have been considered are:

- o Initial procurement and life cycle cost
- o Reliability
- o Maintainability
- o System compatibility
- o System flexibility (modular growth)
- o Availability.

As shown in Section 11.2 of the report, the evaluation of currently available state-of-the-art computer systems has resulted in the recommendation of the Interdata 8/32 as the most technically acceptable and cost effective system for the FCIS(LM).

In order to provide the complete system simulation and advanced training/performance monitoring capabilities required of the FCIS(LM), a dual computer multiprocessor system is defined, with associated peripheral equipments and spare computer time and memory required for future program development. The multiprocessor configuration with multi-port shared memory provides a 50% spare processing capability (time and memory), and growth capability by the addition of processors and/or memory.

The computer operating system, higher order language compiler, executive software and support software requirements have been specified to include those features necessary in a large real-time simulator.

A versatile general-purpose operating system is required which will support a multiprocessor, multiprogramming environment with a large number of users tasks written in assembly language or FORTRAN.

Supervisor (real-time executive) programs have been specified including those required for master control, interface I/O, frame and cycle time verification, intercomputer synchronization, and background activiites.

Additional off-line support programs have also been identified for mission support, maintenance and test, calibration tests, and program development, test and modification.

The FCIS (LM) program has been specified to be designed as a group of modular subprograms using top-down, structured programming concepts. The higher order language determined to be most desirable for use on the FCIS is FORTRAN. This language should be utilized to the maximum extent possible.

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